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Date

November 18, 2008

Signature



Yoshito FUKUSHIMA

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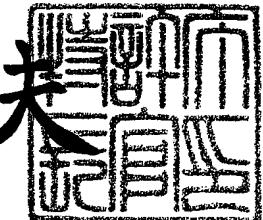
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【Requirement of Proof】 Yes

[Document Name] Specification

[Title of the Invention] Organic Light Emitting Device

[Scope of Claim for Patent]

[Claim 1] An organic electroluminescent device  
5 including a light emitting layer between a hole injection layer  
and an electron injection layer, characterized in that

10 said light emitting layer containing two or more types  
of different luminescent materials, and at least one of said  
two or more types of different luminescent materials being  
a phosphorescent material.

[Claim 2] The organic electroluminescent device as  
recited in claim 1, characterized in that

15 said light emitting layer comprises a short wavelength  
light emitting layer and a long wavelength light emitting layer,  
at least one of the peak wavelengths of light emitted by said  
short wavelength light emitting layer being in a range of 430  
nm to 520 nm, and at least one of the peak wavelengths of light  
emitted by said long wavelength light emitting layer being in  
a range of 520 nm to 630 nm.

20 [Claim 3] The organic electroluminescent device as  
recited in claim 2, characterized in that

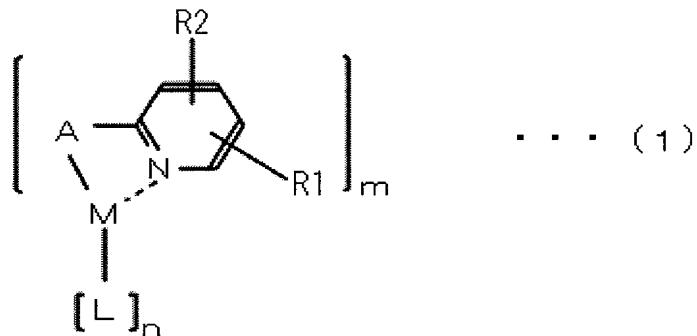
25 said long wavelength light emitting layer includes a first  
host material and a first phosphorescent material, and

30 said first phosphorescent material has a molecular  
structure expressed by the following formula (1), and  
in the formula (1), A is a substituent, R1 and R2 are

the same or different from each other, and are each a hydrogen atom, a halogen atom, or a substituent, L is a substituent, M is a heavy metal, m is 1, 2, or 3, and m and n satisfy a relationship of  $2m + 2n = 6$  or  $2m + n = 6$ .

5

[Formula 1]



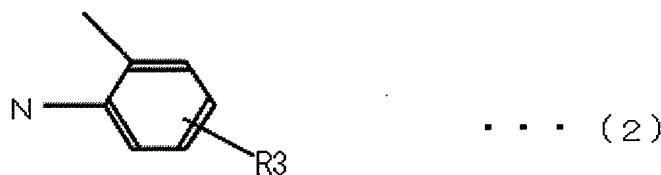
[Claim 4] The organic electroluminescent device as recited in claim 3, characterized in that

said R1 is a hydrogen atom,

10 said R2 has a molecular structure expressed by the following formula (2), and

R3 in the formula (2) is a hydrogen atom, a halogen atom, or a substituent.

[Formula 2]



15

[Claim 5] The organic electroluminescent device as

recited in claim 3 or 4, characterized in that  
said A has a molecular structure expressed by the following  
formula (3), and

5 R4 in the formula (3) is a hydrogen atom, a halogen atom,  
or a substituent.

[Formula 3]

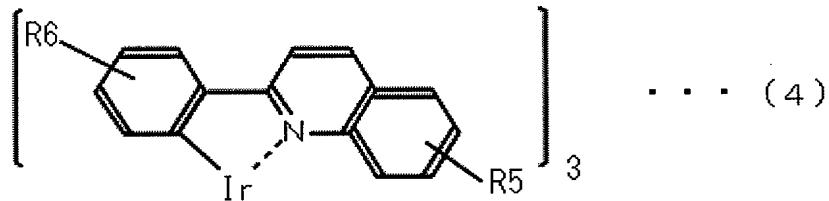


[Claim 6] The organic electroluminescent device as  
recited in any of claims 3 to 5, characterized in that

10 said first phosphorescent material has a  
Tris(2-phenylquinoline)iridium skeleton having a molecular  
structure expressed by the following formula (4), and

15 R5 and R6 in the formula (4) are the same or different  
from each other, and are each a hydrogen atom, a halogen atom,  
or a substituent.

[Formula 4]



[Claim 7] The organic electroluminescent device as  
recited in any of claims 3 to 6, characterized by further  
20 comprising an anode and a cathode, wherein

said long wavelength light emitting layer and said short wavelength light emitting layer are formed in this order between said anode and said cathode, and

5 said long wavelength light emitting layer further contains a first assisting dopant having a hole transport capability.

[Claim 8] The organic electroluminescent device as recited in claim 7, characterized in that

the volume ratio of the sum of said first phosphorescent material and said first assisting dopant to said long wavelength 10 light emitting layer is 3 to 40 %.

[Claim 9] The organic electroluminescent device as recited in claim 7 or 8, characterized in that

the energy level H5 of the highest occupied molecular orbit of said first host material, the energy level H4 of the 15 highest occupied molecular orbit of said first phosphorescent material, and the energy level H6 of the highest occupied molecular orbit of said first assisting dopant satisfy relationships given by the following expressions (5) to (7).

$$H4 < H6 < H5 \dots (5)$$

20  $|H6 - H4| < 0.4 \text{ eV} \dots (6)$

$$|H5 - H6| < 0.4 \text{ eV} \dots (7)$$

[Claim 10] The organic electroluminescent device as recited in any of claims 7 to 9, characterized in that

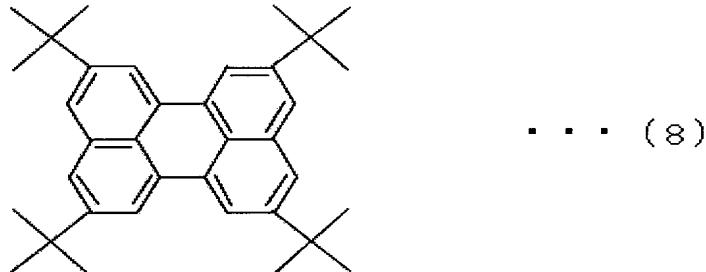
25 said first assisting dopant is composed of an amine-based material, an anthracene derivative, or an iridium complex.

[Claim 11] The organic electroluminescent device as

recited in any of claims 3 to 10, characterized in that  
the ratio of the maximum peak luminous intensity of the  
light emitted by said long wavelength light emitting layer to  
the maximum peak luminous intensity of the light emitted by  
5 said short wavelength light emitting layer is 100 : 20 to 100 :  
100.

[Claim 12] The organic electroluminescent device as  
recited in any of claims 2 to 6, characterized in that  
said short wavelength layer contains a second host  
10 material and a second phosphorescent material,  
said second phosphorescent material has a molecular  
structure expressed by the following formula (8), and  
in the formula (8), B1 is a substituent.

[Formula 5]



15

[Claim 13] The organic electroluminescent device as  
recited in claim 12, characterized by further comprising an  
anode and a cathode, wherein  
said short wavelength light emitting layer and said long  
20 wavelength light emitting layer are formed in this order between  
said anode and said cathode, and

said short wavelength light emitting layer further contains a second assisting dopant having a hole transport capability.

[Claim 14] The organic electroluminescent device as 5 recited in claim 13, characterized in that

the volume ratio of the sum of said second phosphorescent material and said second assisting dopant to said short wavelength light emitting layer is 3 to 40 %.

[Claim 15] The organic electroluminescent device as 10 received in claim 13 or 14, characterized in that

the energy level H3 of the highest occupied molecular orbit of said second host material, the energy level H1 of the highest occupied molecular orbit of said second phosphorescent material, and the energy level H2 of the highest occupied 15 molecular orbit of the second assisting dopant satisfy a relationship given by the following expression (9).

$$H2 < H1 < H3 \quad \dots \quad (9)$$

[Claim 16] The organic electroluminescent device as recited in any of claims 13 to 15, characterized in that

20 said second assisting dopant is composed of an amine-based material, an anthracene derivative, or an iridium complex.

[Claim 17] The organic electroluminescent device, as recited in any of claims 12 to 16, characterized in that

25 the ratio of the maximum peak luminous intensity of the light emitted by said short wavelength light emitting layer to the maximum peak luminous intensity of the light emitted

by said long wavelength light emitting layer is 100 : 20 to 100 : 100.

[Detailed Description of the Invention]

[0001]

5 [Technical Field to which the Invention Belongs]

The present invention relates to an organic electroluminescent device (hereinafter referred to as an organic EL device).

[0002]

10 [Conventional Art]

In recent years, with the prosperity of information technology (IT), demands for thin type display devices that are of a thin type having a thickness of several millimeters and can perform full-color display have increased. As such 15 thin type display devices, the development of organic EL devices has been advanced.

[0003]

Examples of methods of realizing full-color display include a method using a red light emitting device, a green 20 light emitting device, and a blue light emitting device (see Patent Document 1, for example) and a method using a combination of a white light emitting device and color filters for transmitting monochromatic lights in the three primary colors. The white light emitting device includes a blue luminescent 25 material and an orange luminescent material, to realize a white color by simultaneously emitting blue light emitted by the blue

luminescent material and orange light emitted by the orange luminescent material.

[0004]

[Patent Document 1]

5 JP 2001-93667 A

[Nonpatent Document 1]

J. kido, M. Kimura, K. Nagai, Science, 267, 1332, 1995

[0005]

[Problems to be Solved by the Invention]

10 When white luminescence is realized using the blue luminescent material and the orange luminescent material, however, high efficiency as a white color cannot be realized unless the blue light and the orange light are emitted at a high efficiency. In a conventional white light emitting device, 15 the limit is a luminous efficiency of 10 cd/A (see Nonpatent Document 1, for example).

[0006]

On the other hand, when a white light emitting device and color filters are combined to perform full-color display, 20 a part of white light is absorbed because of loss of luminous efficiency caused by the color filters, so that light having a high luminance is not obtained. In a case where the white light emitting device and the color filters are combined to perform full-color display, therefore, the power consumption 25 is higher and the luminance is lower, as compared with those in a case where the red light emitting device, the green light

emitting device, and the blue light emitting device are used to perform full-color display.

[0007]

An object of the present invention is to provide an organic 5 electroluminescent device that can emit white light outward at a high efficiency.

[0008]

[Means for Solving the Problems and Effects of the Invention]

10 An organic electroluminescent device according to the present invention includes a light emitting layer between a hole injection layer and an electron injection layer, the light emitting layer comprising two or more types of different luminescent materials, and at least one of the two or more types 15 of different luminescent materials being a phosphorescent material.

[0009]

In the organic electroluminescent device according to the present invention, holes are supplied from the hole injection 20 layer, and electrons are supplied from the electron injection layer to the light emitting layer. Consequently, the two or more types of difference luminescent materials contained in the light emitting layer respectively emit lights. In this case, one or more of the lights are phosphorescence. Therefore, 25 the light emitting layer emit light having a high intensity. As a result, white light can be emitted outward at a high

efficiency.

[0010]

The light emitting layer may comprise a short wavelength light emitting layer and a long wavelength light emitting layer.

5 At least one of the peak wavelengths of light emitted by the short wavelength light emitting layer may be in a range of 430 nm to 520 nm, and at least one of the peak wavelengths of light emitted by the long wavelength light emitting layer may be in a range of 520 nm to 630 nm.

10 [0011]

In this case, the short wavelength light emitting layer mainly emits blue light, and the long wavelength light emitting layer mainly emits orange light. Consequently, white light can be emitted outward at a high efficiency.

15 [0012]

The long wavelength light emitting layer may further contain a first host material and a first phosphorescent material, the first phosphorescent material may have a molecular structure expressed by the following formula (1). In the formula (1),

20 A may be a substituent, R1 and R2 may be the same or different from each other, and may be each a hydrogen atom, a halogen atom, or a substituent, L may be a substituent, M may be a heavy metal, m may be 1, 2, or 3, and m and n may satisfy a relationship of  $2m + 2n = 6$  or  $2m + n = 6$ .

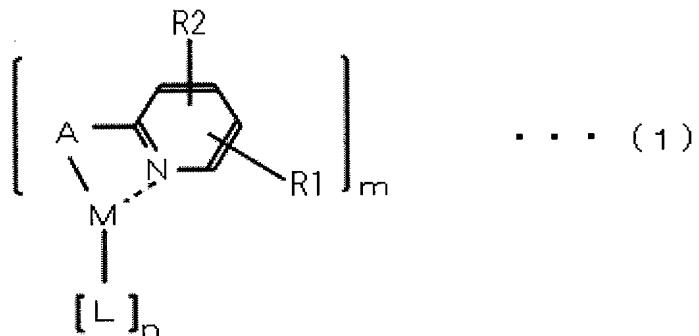
25 [0013]

In this case, the long wavelength light emitting layer

emits orange light having a high intensity. Consequently, white light can be emitted outward at a high efficiency.

[0014]

5 [Formula 6]



[0015]

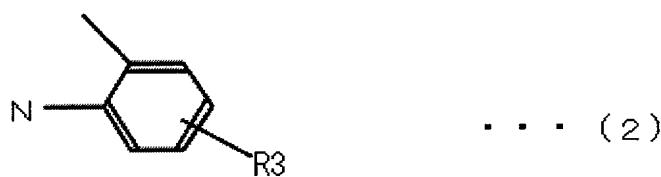
The R1 may be a hydrogen atom, the R2 may have a molecular structure expressed by the following formula (2), and R3 in the formula (2) may be a hydrogen atom, a halogen atom, or a substituent.

[0016]

In this case, the long wavelength light emitting layer emits orange light having a high intensity. Consequently, white light can be emitted outward at a high efficiency.

[0017]

[Formula 7]



[0018]

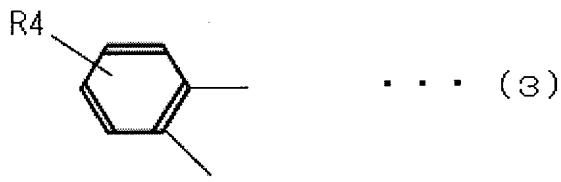
The A may have a molecular structure expressed by the following formula (3), and R4 in the formula (3) may be a hydrogen atom, a halogen atom, or a substituent.

5 [0019]

In this case, the long wavelength light emitting layer emits orange light having a high intensity. Consequently, white light can be emitted outward at a high efficiency.

[0020]

10 [Formula 8]



[0021]

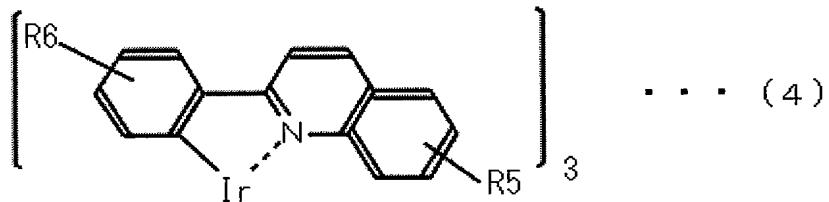
The first phosphorescent material may have a Tris(2-phenylquinoline)iridium skeleton having a molecular structure expressed by the following formula (4), and R5 and R6 in the formula (4) may be the same or different from each other, and may be each a hydrogen atom, a halogen atom, or a substituent.

[0022]

20 In this case, the long wavelength light emitting layer emits orange light having a high intensity. Consequently, white light can be emitted outward at a high efficiency.

[0023]

[Formula 9]



[0024]

An anode and a cathode may further be included. The long wavelength light emitting layer and the short wavelength light emitting layer may be formed in this order between the anode and the cathode, and the long wavelength light emitting layer may further contain a first assisting dopant having a hole transport capability.

10 [0025]

In this case, holes supplied from the anode to the long wavelength light emitting layer easily pass through the long wavelength light emitting layer. Consequently, the supplied holes and electrons supplied from the cathode to the short wavelength light emitting layer are easily recombined with each other in the short wavelength light emitting layer. Therefore, recombination of almost all of the holes supplied from the anode to the long wavelength light emitting layer with the electrons in the long wavelength light emitting layer is prevented, thereby preventing the luminous intensity of the orange light emitted by the long wavelength light emitting layer from being higher than the luminous intensity of the blue light emitted by the short wavelength light emitting layer.

[0026]

The volume ratio of the sum of the first phosphorescent material and the first assisting dopant to the long wavelength light emitting layer may be 3 to 40 %. In this case, the holes 5 supplied from the anode to the long wavelength light emitting layer easily pass through the long wavelength light emitting layer. Therefore, the supplied holes and electrons are easily recombined with each other in the short wavelength light emitting layer.

10 [0027]

The energy level H5 of the highest occupied molecular orbit of the first host material, the energy level H4 of the highest occupied molecular orbit of the first phosphorescent material, and the energy level H6 of the highest occupied 15 molecular orbit of the first assisting dopant may satisfy relationships given by the following expressions (5) to (7):

[0028]

$$H4 < H6 < H5 \quad \dots \quad (5)$$

$$|H6 - H4| < 0.4 \text{ eV} \quad \dots \quad (6)$$

20 
$$|H5 - H6| < 0.4 \text{ eV} \quad \dots \quad (7)$$

In this case, the holes supplied from the anode to the long wavelength light emitting layer easily pass through the long wavelength light emitting layer. Therefore, the supplied holes and electrons are easily recombined with each other in 25 the short wavelength light emitting layer.

[0029]

The first assisting dopant may be composed of an amine-based material, an anthracene derivative, or an iridium complex. In this case, the holes supplied from the anode to the long wavelength light emitting layer easily pass through the long wavelength light emitting layer. Therefore, the supplied holes and electrons are easily recombined with each other in the short wavelength light emitting layer.

[0030]

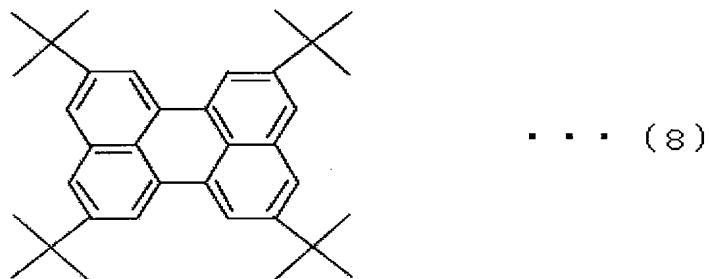
The ratio of the maximum peak luminous intensity of the light emitted by the long wavelength light emitting layer to the maximum peak luminous intensity of the light emitted by the short wavelength light emitting layer may be 100 : 20 to 100 : 100. In this case, the intensity of the orange light and the intensity of the blue light are approximately the same. Consequently, white light can be emitted outward at a high efficiency.

[0031]

The short wavelength layer may contain a second host material and a second phosphorescent material, the second phosphorescent material may have a molecular structure expressed by the following formula (8), and in the formula (8), B1 may be a substituent.

[0032]

[Formula 10]



[0033]

5 In this case, the short wavelength light emitting layer  
 emits blue light having a high intensity. Consequently, white  
 light can be emitted outward at a high efficiency.

[0034]

10 An anode and a cathode may further be included. The short wavelength light emitting layer and the long wavelength light emitting layer may be formed in this order between the anode and the cathode, and the short wavelength light emitting layer may further contain a second assisting dopant having a hole transport capability.

[0035]

15 In this case, holes supplied from the anode to the short wavelength light emitting layer easily pass through the short wavelength light emitting layer. Consequently, the supplied holes and electrons supplied from the cathode to the long wavelength light emitting layer are easily recombined with each  
 20 other in the long wavelength light emitting layer. Therefore, recombination of almost all of the holes supplied from the anode

to the short wavelength light emitting layer with the electrons in the short wavelength light emitting layer is prevented, thereby preventing the luminous intensity of the orange light emitted by the short wavelength light emitting 5 layer from being higher than the luminous intensity of the orange light emitted by the long wavelength light emitting layer.

[0036]

The volume ratio of the sum of the second phosphorescent material and the second assisting dopant to the short wavelength 10 light emitting layer may be 3 to 40 %. In this case, the holes supplied from the anode to the short wavelength light emitting layer easily pass through the short wavelength light emitting layer. Therefore, the supplied holes and electrons are easily recombined with each other in the long wavelength light emitting 15 layer.

[0037]

The energy level H3 of the highest occupied molecular orbit of the second host material, the energy level H1 of the highest occupied molecular orbit of the second phosphorescent 20 material, and the energy level H2 of the highest occupied molecular orbit of the second assisting dopant may satisfy a relationship given by (9).

[0038]

$$H2 < H1 < H3 \dots (9)$$

25 In this case, the holes supplied from the anode to the short wavelength light emitting layer easily pass through the

short wavelength light emitting layer. Therefore, the supplied holes and electrons are easily recombined with each other in the long wavelength light emitting layer.

[0039]

5 The second assisting dopant may be composed of an amine-based material, an anthracene derivative, or an iridium complex. In this case, the holes supplied from the anode to the short wavelength light emitting layer easily pass through the short wavelength light emitting layer. Therefore, the 10 supplied holes and electrons are easily recombined with each other in the long wavelength light emitting layer.

[0040]

15 The ratio of the maximum peak luminous intensity of the light emitted by the short wavelength light emitting layer to the maximum peak luminous intensity of the light emitted by the long wavelength light emitting layer may be 100 : 20 to 100 : 100. In this case, the intensity of the blue light and the intensity of the orange light are approximately the same. Consequently, white light can be emitted outward at a high 20 efficiency.

[0041]

[Embodiments of the Invention]

(First Embodiment)

Fig. 1 is a schematic sectional view showing an organic 25 EL device according to a first embodiment of the present invention.

[0042]

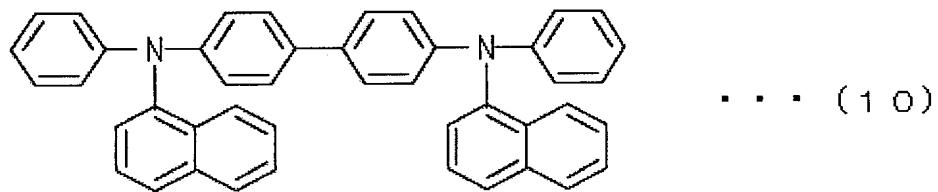
In fabrication of an organic EL device 100 shown in Fig. 1, an anode 2 composed of  $\text{In}_2\text{O}_3\text{-SnO}_2$  (ITO) is previously formed on a glass substrate 1, and a hole injection layer 3, a hole transport layer 4, a blue light emitting layer 5, an 5 orange light emitting layer 6, an electron transport layer 7, and an electron injection layer 8 are formed in this order by a vapor deposition at a vacuum in the  $10^{-4}\text{Pa}$  order, to form an organic thin film layer 10. Further, a cathode 9 composed of an alloy of magnesium and indium (Mg : In) is formed on the 10 organic thin film layer 10.

[0043]

The hole transport layer 4 is composed of an amine-based material such as  $\text{N},\text{N}'\text{-Di}(\text{naphthalene-1-yl})\text{-N},\text{N}'\text{-diphenyl-benzidine}$  15 (hereinafter referred to as NPB) having a molecular structure expressed by the following formula (10),  $4,4',4''\text{-Tris}(\text{N-}(2\text{-naphthyl})\text{-N-phenyl-amino})\text{-triphenylamine}$  (hereinafter referred to as 2TNATA) having a molecular structure expressed by the following formula (11), and 20  $\text{N},\text{N}'\text{-Bis-}(3\text{-methylphenyl})\text{-N},\text{N}'\text{-bis-}(\text{phenyl})\text{-benzidine}$  (hereinafter referred to as TPD), for example:

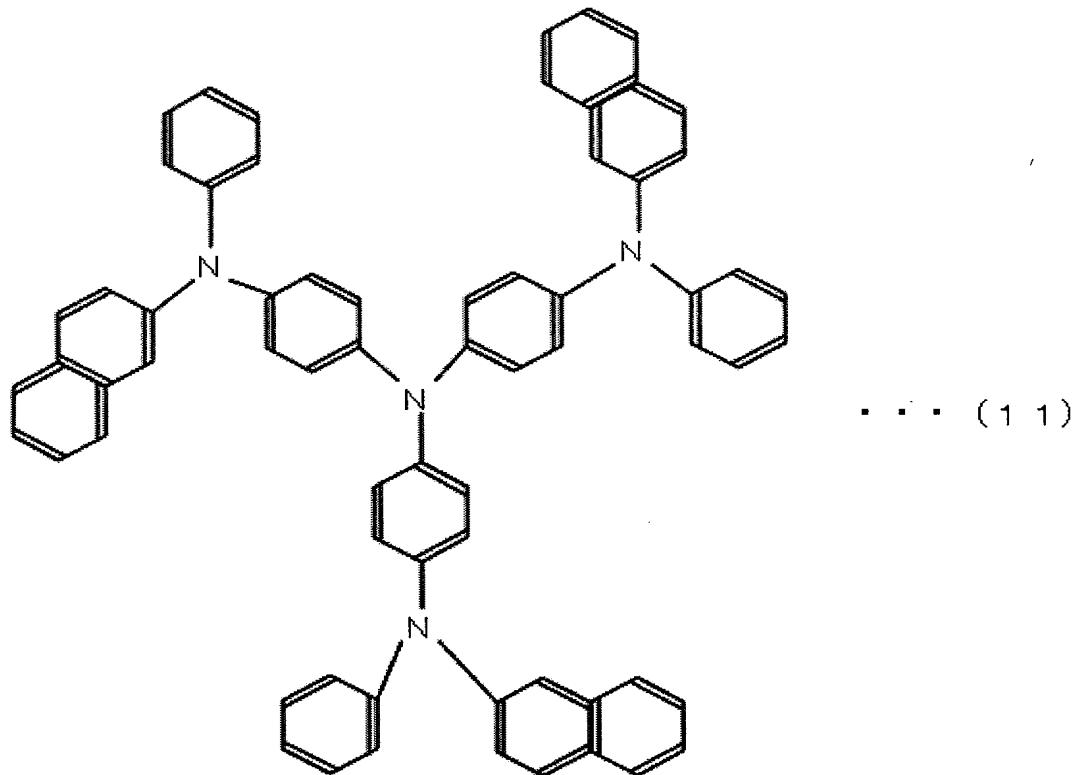
[0044]

[Formula 11]



[0045]

[Formula 12]



5

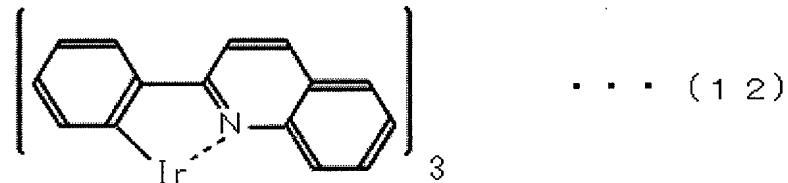
[0046]

The hole transport layer 4 may be composed of an anthracene derivative such as Rubrene having a molecular structure expressed by the following formula (12) or 10 Tris(2-phenylpyridine) indium (hereinafter referred to as Ir(ppy)<sub>3</sub>) having a molecular structure expressed by the

following formula (13):

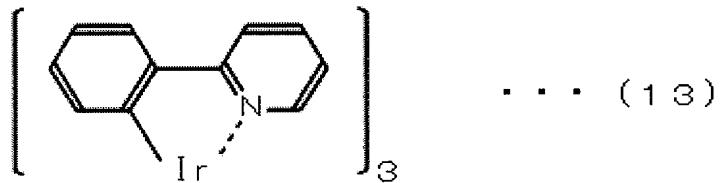
[0047]

[Formula 13]



5 [0048]

[Formula 14]



[0049]

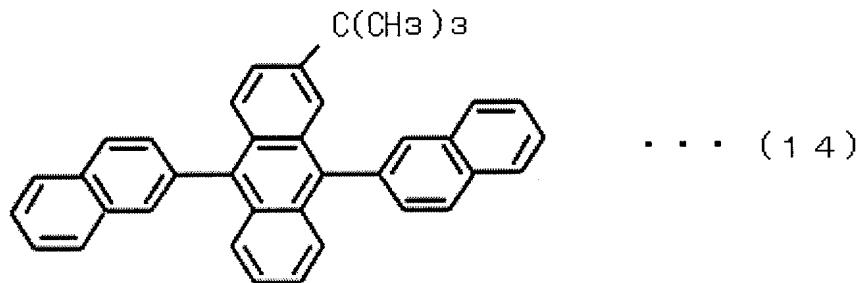
The blue light emitting layer 5 is composed of a host  
10 material doped with a luminescent dopant and an assisting dopant.

[0050]

The host material composing the blue light emitting layer  
5 is composed of *tert*-butyl substituted di-naphthyl anthracene  
15 (hereinafter referred to as a compound A) having a molecular  
structure expressed by the following formula (14), for example:

[0051]

[Formula 15]

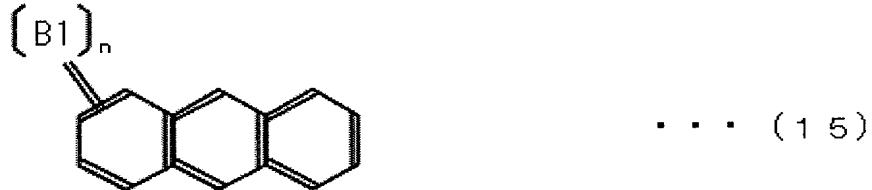


[0052]

It is preferable that the luminescent dopant to be doped  
 5 into the host material composing the blue light emitting layer  
 5 has a molecular structure of the following formula (15).

[0053]

[Formula 16]



10 [0054]

In the formula (15), B1 represents a substituent, described later, and n is an integer 1 through 10. When n is not less than two, the substituents B1 may be the same or different. B1 is an anyl group such as a phenyl group or a hetero aryl group, for example, the hetero atom may have an oxygen atom, a sulfur atom, or a nitrogen atom and/or a halogen atom, may have a substituent selected from a hydroxy group, an amino group, a sulfo group, a phospho group, a carboxy group, an aldehyde group, a carbazole group, or the like, or may have an oxygen

atom, a sulfur atom, or a nitrogen atom and/or a halogen atom and the above-mentioned substituent. Further, B1 may be substituted for any cite of the anthracene ring, or a plurality of R20 may be substituted for the anthracene ring. 5 B1 may be a plurality of substituents which differ from one another.

[0055]

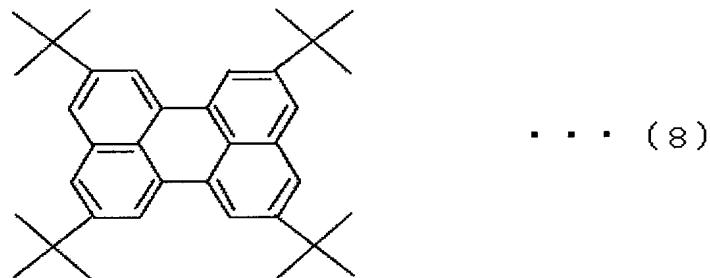
The peak wavelength of the intensity of light emitted by the luminescent dopant is 430 nm to 510 nm. Therefore, the 10 blue light emitting layer 5 mainly emits blue light.

[0056]

An example of the luminescent dopant to be doped into the host material composing the blue light emitting layer 5 is 1,4,7,10-Tetra-*tert*-butylPerylene (hereinafter referred to 15 as TBP) having a molecular structure expressed by the following formula (8):

[0057]

[Formula 17]



20 [0058]

An example of the assisting dopant to be doped into the

host material composing the blue light emitting layer 5 is NPB or Rubrene used for the hole transport layer 4.

[0059]

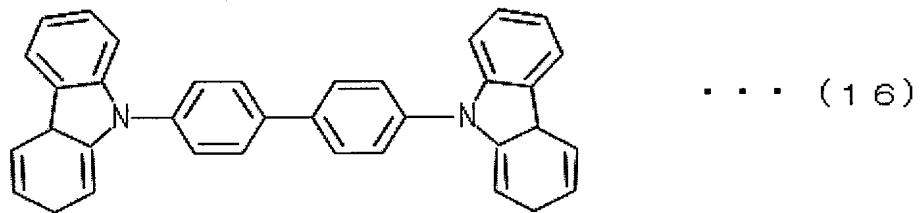
In the blue light emitting layer 5, the volume ratio of 5 the luminescent dopant to the host material is approximately 2 %, and the volume ratio of the assisting dopant thereto is 0 % to 40 %, for example. The volume ratio of the assisting dopant is preferably 3 % to 40 %.

[0060]

10 The orange light emitting layer 6 is composed of a host material doped with a luminescent dopant. The host material composing the orange light emitting layer 6 is composed of 4,4'-Bis(carbazol-9-yl)-biphenyl (hereinafter referred to as CBP) having a molecular structure expressed by the following 15 formula (16), for example:

[0061]

[Formula 18]



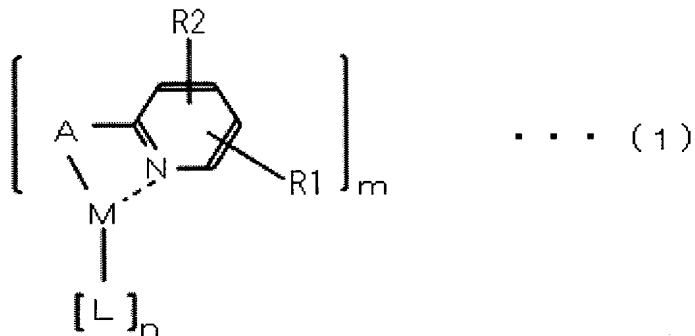
[0062]

20 It is preferable that the luminescent dopant to be doped into the host material composing the orange light emitting layer 6 has a molecular structure expressed by the following formula

(1). In the formula (1), R<sub>1</sub> and R<sub>2</sub> are the same or different from each other, and are each a hydrogen atom, a halogen atom, or a substituent, A is a substituent, L is a ligand, and M is a heavy metal.

5 [0063]

[Formula 19]



[0064]

Examples of the substituents R<sub>1</sub> and R<sub>2</sub> are a cyano group, 10 a silyl group, an alkynyl group, an alkenyl group, an alkoxy group, a hydroxy group, an amino group, a nitro group, a nitrile group, a sulfo group, a carboxy group, an aldehyde group, or the like, which is saturated or unsaturated straight-chain or branched chain having a maximum of 20 carbon atoms.

15 [0065]

Alternative examples of the substituents R<sub>1</sub> and R<sub>2</sub> are an aryl group, a heteroaromatic group, a condensed aromatic group, or the like which is condensed with a pyridine ring. The groups each have an alkyl group, an alkenyl group, an acyclo 20 alkyl group, an aryl group, or the like. The aryl group is a phenyl group or a hetero aryl group, for example, the hetero

atom may have an oxygen atom, a sulfur atom, or a nitrogen atom, a substituent selected from a halogen, a hydroxy group, an amino group, a sulfo group, a phospho group, a carboxy group, an aldehyde group, and the like. R1 and R2 may be combined 5 with each other or cyclized.

[0066]

In the foregoing formula (1), R1 may be a hydrogen atom, and R2 may be a substituent expressed by the following formula 10 (2). R3 in the following formula (2) is a hydrogen atom, a halogen atom, or a substituent.

[0067]

[Formula 20]



[0068]

15 Each of the substituent R3 may be  $-C_nH_{2n+1}$  ( $n=0-10$ ), a phenyl group, a naphthyl group, a thiophene group,  $-CN$ ,  $-N(C_nH_{2n+1})_2$  ( $n=1-10$ ),  $-COOC_nH_{2n+1}$  ( $n=1-10$ ),  $-F$ ,  $-Cl$ ,  $-Br$ ,  $-I$ ,  $-OCH_3$ ,  $-OC_2H_5$ , or the like.

[0069]

20 Examples of the ligand L in the foregoing formula (1) may be a halogen ligand, a carboxylic acid ligand such as picolinic acid or salicylic acid, an imine ligand, a diketone ligand such as acetylacetone or dibenzoylmethane, a phosphorous

ligand, an ortho carbometallation ligand such as phenyl pyridine, etc.

[0070]

The heavy metal M in the foregoing formula (1) may be 5 platinum, palladium, iridium, rhodium, rhenium, or the like.

[0071]

m and n in the foregoing formula (1) satisfy a relationship of  $2m + 2n = 6$  or  $2m + n = 6$  ( $m = 1, 2, 3$ ). L is a single-seated or double-seated ligand with respect to M.

10 [0072]

The substituent A in the foregoing formula (1) may be expressed by the following formula (3):

[0073]

[Formula 21]



15

[0074]

R4 in the foregoing formula (3) is a hydrogen atom, a halogen atom, or a substituent. Examples of the substituent R4 may be  $-C_nH_{2n+1}$  ( $n=0-10$ ), a phenyl group, a naphthyl group, 20 a thiophene group,  $-CN$ ,  $-N(C_nH_{2n+1})_2$  ( $n=1-10$ ),  $-COOC_nH_{2n+1}$  ( $n=1-10$ ),  $-F$ ,  $-Cl$ ,  $-Br$ ,  $-I$ ,  $-OCH_3$ ,  $-OC_2H_5$ , or the like.

[0075]

The compound expressed by the foregoing formula (1) may

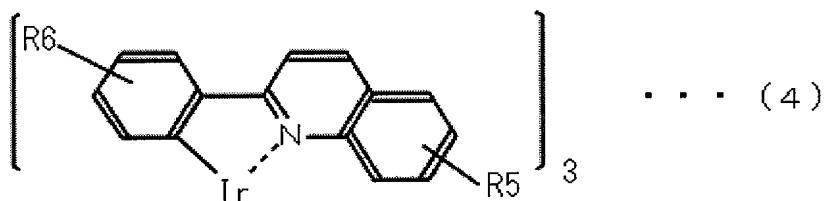
have

a

Tris(2-phenylquinoline)iridium (hereinafter referred to as Ir(phenq)) skeleton having a molecular structure expressed by the following formula (4):

5 [0076]

[Formula 22]



[0077]

10 R5 and R6 in the foregoing formula (4) are each a halogen atom or a substituent. R4 in the formula (4) indicates a hydrogen atom, a halogen atom, or a substituent. Examples of the substituents R5 and R6 may be each  $-C_nH_{2n+1}$  ( $n=0-10$ ), a phenyl group, a naphthyl group, a thiophene group, -CN,  $-N(C_nH_{2n+1})_2$  15 ( $n=1-10$ ),  $-COOC_nH_{2n+1}$  ( $n=1-10$ ), -F, -Cl, -Br, -I, -OCH<sub>3</sub>, -OC<sub>2</sub>H<sub>5</sub>, or the like.

[0078]

20 The peak wavelength of the intensity of light emitted by the luminescent dopant is 520 nm to 680 nm. Therefore, the orange light emitting layer 6 mainly emits orange light. In the orange light emitting layer 6, the ratio of the thickness corresponding to the luminescent dopant to the thickness corresponding to the host material is approximately 6.5 %.

[0079]

Fig. 2 is a diagram showing the energy levels of the lowest unoccupied molecular orbit (LUMO) and the highest occupied molecular orbit (HOMO) of each of the hole transport layer 4, 5 the blue light emitting layer 5, the host material, the luminescent dopant, and the assisting dopant in the organic EL device according to the first embodiment.

[0080]

As described in Fig. 1, the hole transport layer 4 and 10 the assisting dopant use the same material. Accordingly, the HOMO level H0 of the hole transport layer 4 and the HOMO level H1 of the assisting dopant are the same energy level.

[0081]

As shown in Fig. 2, in the blue light emitting layer 5, 15 a relationship of (the HOMO level H1 of the assisting dopant) < (the HOMO level H2 of the luminescent dopant) < (the HOMO level H3 of the host material) holds. The energy of holes increases along an arrow.

[0082]

20 Therefore, holes supplied from the hole transport layer 4 to the blue light emitting layer 5 easily pass through the blue light emitting layer 5 to easily reach the orange light emitting layer 6 shown in Fig. 1. As a result, electrons and holes are easily recombined with each other in the orange light 25 emitting layer 6, so that the intensity of light emitted by the orange light emitting layer 6 is increased. Consequently,

recombination of almost all of the holes supplied from the hole transport layer 4 to the blue light emitting layer 5 with electrons in the blue light emitting layer 5 is prevented, thereby preventing the luminous intensity of the blue light emitted by the blue light emitting layer 5 from being higher than the luminous intensity of the orange light emitted by the orange light emitting layer 6.

[0083]

In this case, the ratio of the intensity of the blue light emitted by the blue light emitting layer 5 to the intensity of the orange light emitted by the orange light emitting layer 6 is 100 : 20 to 100 : 100. Consequently, the organic EL device shown in Fig. 1 can efficiently emit white light.

[0084]

In the present embodiment, the blue light emitting layer 5 corresponds to a short wavelength light emitting layer, the orange light emitting layer 6 corresponds to a long wavelength light emitting layer, the host material composing the blue light emitting layer 5 corresponds to a first host material, the luminescent dopant to be doped into the host material composing the blue light emitting layer 5 corresponds to a first phosphorescent material, the assisting dopant to be doped into the host material composing the blue light emitting layer 5 corresponds to a first assisting dopant, the host material composing the orange light emitting layer 6 corresponds to a second host material, the luminescent dopant to be doped into

the host material composing the orange light emitting layer 6 corresponds to a second phosphorescent material, and the assisting dopant to be doped into the host material composing the orange light emitting layer 6 corresponds to a second assisting dopant.

5 [0085]

(Second Embodiment)

Fig. 3 is a schematic sectional view showing an organic EL device according to a second embodiment.

10 [0086]

The organic EL device shown in Fig. 3 differs from the organic EL device shown in Fig. 1 in that a blue light emitting layer 5a and an orange light emitting layer 6a shown in Fig. 3 are formed in an order reverse to the blue light emitting layer 5 and the orange light emitting layer 6 shown in Fig. 15 Fig. 1.

1. [0087]

The orange light emitting layer 6a has a structure in which the assisting dopant is doped into the host material composing the orange light emitting layer 6 shown in Fig. 1. An example of an assisting dopant to be doped into a host material composing the orange light emitting layer 6a is NPB, Rubrene, or Ir(ppy) used for a hole transport layer 4.

[0088]

25 In the orange light emitting layer 6a, the volume ratio of a luminescent dopant to the host material is approximately

6.5 %, and the volume ratio of the assisting dopant thereto is 0 % to 40 %, for example. The volume ratio of the assisting dopant is preferably 3 % to 40 %.

[0089]

5 The blue light emitting layer 5a has a structure in which no assisting dopant is doped into the host material composing the blue light emitting layer 5 shown in Fig. 1.

[0090]

Fig. 4 is a diagram showing the energy levels of the lowest 10 unoccupied molecular orbit (LUMO) and the highest occupied molecular orbit (HOMO) of each of the hole transport layer 4, the orange light emitting layer 6a, the dopant, and the assisting dopant in the organic EL device according to the second embodiment.

[0091]

15 As described in Fig. 3, the hole transport layer 4 and the assisting dopant may use the same material. Accordingly, the HOMO level H0 of the hole transport layer 4 and the HOMO level H1 of the assisting dopant are the same energy level.

[0092]

20 As shown in Fig. 3, in the orange light emitting layer 6a, a relationship of (the HOMO level H4 of the luminescent dopant) < (the HOMO level H1 of the assisting dopant) < (the HOMO level H5 of the host material) holds. With respect to each of the HOMO levels, a relationship of |(the HOMO level 25 H1 of the assisting dopant) - (the HOMO level H4 of the luminescent dopant) | < 0.4 eV holds and a relationship of |(the HOMO level

H5 of the host material) - (the HOMO level H1 of the assisting dopant) | < 0.4 eV.

[0093]

Therefore, holes supplied from the hole transport layer 5 to the orange light emitting layer 6a easily pass through the orange light emitting layer 6a to easily reach the blue light emitting layer 5a shown in Fig. 3. As a result, electrons and holes are easily recombined with each other in the blue light emitting layer 5a, so that the intensity of light emitted by the blue light emitting layer 5a is increased.

[0094]

Therefore, holes supplied from the hole transport layer 4 to the orange light emitting layer 6a easily pass through the orange light emitting layer 6a to easily reach the blue light emitting layer 5a shown in Fig. 3. As a result, electrons and holes are easily recombined with each other in the blue light emitting layer 5a. Consequently, recombination of almost all of the holes supplied from the hole transport layer 4 to the orange light emitting layer 6a with electrons in the orange light emitting layer 6a is prevented, thereby preventing the luminous intensity of orange light emitted by the orange light emitting layer 6a from being higher than the luminous intensity of blue light emitted by the blue light emitting layer 5a.

[0095]

In this case, the ratio of the intensity of the orange light emitted by the orange light emitting layer 6a to the

intensity of the blue light emitted by the blue light emitting layer 5a is 100 : 20 to 100 : 100. Consequently, the organic EL device shown in Fig. 2 can efficiently emit white light.

5 [0096]

[Examples]

In inventive examples 1 to 8, organic electroluminescent devices were prepared by changing the types of host material and dopant used for blue light emitting layers 5 and 5a and 10 orange light emitting layers 6 and 6a and their composition ratios, to examine the effect of the types of host material and dopant and their composition ratios on a luminous efficiency.

[0097]

In Ir (phq) of the structure of the formula (4) used in 15 the inventive examples 1 to 8 and the comparative example 2, each of R5 and R6 indicates the hydrogen atom.

[0098]

Each of the organic EL devices in the inventive examples 1 to 3 and 7 and the comparative example 1 has the structure 20 of the organic EL device according to the first embodiment, where the thickness of the hole injection electrode 3 is 10 nm, the thickness of the hole transport layer 4 is 50 nm, the thickness of the blue light emitting layer 5 is 10 nm, the thickness of the orange light emitting layer 6 is 25 nm, the 25 thickness of the electron transport layer 7 is 20 nm, the thickness of the electron injection layer 8 is 1 nm, and the

thickness of the cathode 9 is 200 nm.

[0099]

Each of the organic EL devices in the inventive examples 4 to 6 and 8 and the comparative example 2 has the structure 5 of the organic EL device according to the second embodiment, where the thickness of the hole injection electrode 3 is 10 nm, the thickness of the hole transport layer 4 is 50 nm, the thickness of the orange light emitting layer 6a is 10 nm, the thickness of the blue light emitting layer 5a is 25 nm, the 10 thickness of the electron transport layer 7 is 20 nm, the thickness of the electron injection layer 8 is 1 nm, and the thickness of the cathode 9 is 200 nm.

[0100]

Hereinafter, each of the structure of the organic EL device 15 according to the first embodiment is referred to as a structure A, and the structure of the organic EL device according to the second embodiment is referred to as a structure B.

[0101]

(Inventive Example 1)

20 In the inventive example 1, the organic EL device having the structure A was prepared. First, the anode 2 was formed on the glass substrate 1 by 80 nm sputtering. The glass substrate 1 having the anode 2 formed thereon was cleaned with a mild detergent and pure water, and was then baked at a temperature 25 of 100°C for not less than 10 hours, followed by UV/O3 cleaning, to set the glass substrate 1 in a chamber of a vacuum evaporation

system which is depressurized to not more than  $1 \times 10^{-4}$  Pa.

[0102]

CuPc was formed as the hole injection layer 3, and NPB was formed by vacuum evaporation as the hole transport layer 4. Then, the compound A was used as a host material, and TBP was used as a luminescent dopant, to form the blue light emitting layer 5. TBP was doped such that the volume ratio thereof to the blue light emitting layer 5 was 2 %.

[0103]

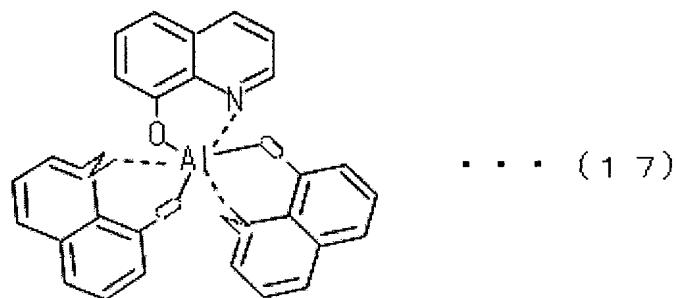
Then, CBP was used as the host material, and Ir(phq) was used as the luminescent dopant, to form the orange light emitting layer 6. Ir(phq) was doped such that the volume ratio thereof to the orange light emitting layer 6 was 6.5 %.

[0104]

Tris(8-hydroxyquinolinato)aluminum (hereinafter referred to as Alq) having a molecular structure expressed by the following formula (17) was then formed as the electron transport layer 7. LiF was formed as the electron transport layer 8, and Al was formed as the cathode 9. The organic EL device was sealed under an atmosphere of a dew point of - 80 °C with adhesives using a glass plate coated with a desiccant. The results are shown in Table 1.

[0105]

[Formula 23]



[0106]

[Table 1]

	blue luminescent layer host material / luminescent opant	blue luminescent layer host material assisting dopant	orange luminescent layer host material / luminescent dopant	orange luminescent layer assisting dopant	luminous color (CIE x, y)	luminous efficiency (cd/A at 10mA/cm <sup>2</sup> )	ratio of peak luminous intensities of blue luminescent 1 layer/orange luminescent layer	drive voltage (V at 10mA/cm <sup>2</sup> )
inventive example 1 A	compound A /TBP	no	CBP/Ir (phq)	no	0.21, 0.36	6.8	100/21	9
inventive example 2 A	compound A /TBP	NPB	CBP/Ir (phq)	no	0.32, 0.37	24.3	100/62	7.1
inventive example 3 A	compound A /TBP	rubrene	CBP/Ir (phq)	no	0.50, 0.42	5.1	23/100	8.2
inventive example 4 B	compound A /TBP	no	CBP/Ir (phq)	NPB	0.41, 0.42	22.7	59/100	7.9
inventive example 5 B	compound A /TBP	no	CBP/Ir (phq)	rubrene	0.50, 0.45	13.8	21/100	8.6
inventive example 6 B	compound A /TBP	no	CBP/Ir (phq)	Ir (ppy)	0.47, 0.43	14.0	26/100	8.2
comparative example 1 A	compound A /TBP	no	Alq/DCJTB	no	0.21, 0.34	2.3	100/8	8.1
comparative example 2 B	compound A /TBP	no	CBP/Ir (phq)	no	0.55, 0.41	19.8	16/100	10.4

[0107]

(Inventive Example 2)

In the inventive example 2, the organic EL device was prepared in the same method as that in the inventive example 5 1 except that TBP was doped into the compound A, and NBP was doped thereinto as the assisting dopant, and TBP and NPB were doped such that the volume ratios thereof to the blue light emitting layer 5 were respectively 2 % and 10 %. The results are shown in Table 1

10 [0108]

(Inventive Example 3)

In the inventive example 3, the organic EL device was prepared in the same method as that in the inventive example 15 2 except that TBP and Rubrene were doped into the compound A instead of doping TBP and NPB thereinto, and TBP and Rubrene were doped such that the volume ratios thereof to the blue light emitting layer 5 were respectively 2 % and 10 %. The results are shown in Table 1.

[0109]

20 (Inventive Example 4)

In the inventive example 4, the organic EL device having the structure B was prepared in the same method as that in the inventive example 1 except for the following. That is, after the hole transport layer 4 was formed, CBP was used as a host 25 material, Ir(phq) was used as a luminescent dopant, and NPB was used as an assisting dopant, to form the orange light emitting

layer 6a. Ir(phq) and NPB were doped such that the volume ratios thereof to the orange light emitting layer 6a were respectively 6.5 % and 10 %.

[0110]

5 After the orange light emitting layer 6a was formed, the compound A was used as a host material, and TBP was used as a luminescent dopant, to form the blue light emitting layer 5a. TBP was doped such that the volume ratio thereof to the blue light emitting layer 5a was 2.0 %. The results are shown  
10 in Table 1.

(Inventive Example 5)

In the inventive example 5, the organic EL device was prepared in the same method as that in the inventive example 4 except that Ir(phq) and Rubrene were doped into CBP instead  
15 of doping Ir(phq) and NPB thereinto, and Ir(phq) and Rubrene were doped such that the volume ratios thereof to the orange light emitting layer 6a were respectively 6.5 % and 10 %.

[0111]

(Inventive Example 6)

20 In the inventive example 6, the organic EL device was prepared in the same method as that in the inventive example 4 except that Ir(phq) and Ir(ppy) were doped into CBP instead of doping Ir(phq) and NPB thereinto, and Ir(phq) and Ir(ppy) were doped such that the volume ratios thereof to the orange  
25 light emitting layer 6a were respectively 6.5 % and 2 %.

[0112]

## (Comparative Example 1)

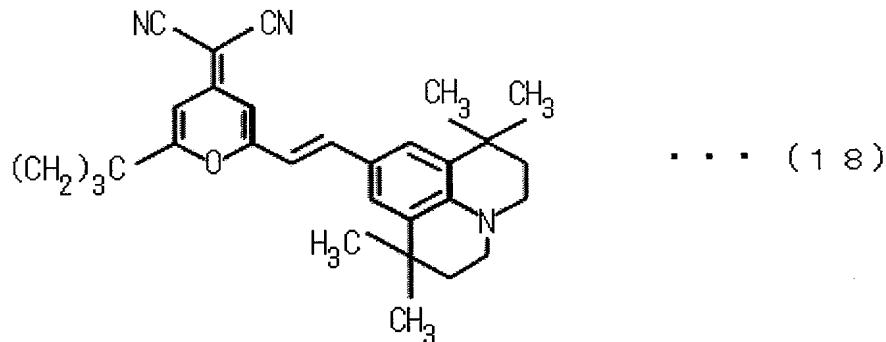
In the comparative example 1, the organic EL device was prepared in the same method as that in the inventive example

1 except that

5 (2-(1,1-Dimethylethyl)-6-(2-(2,3,6,7-tetrahydro-1,1,7,7-te  
tramethyl-1II,5II-benzo { ij }  
quinolizin-9-yl)ethenyl)-4H-pyran-4-ylidene)propanedinitri  
le (hereinafter referred to as DCJTB) having a molecular  
structure expressed by the following formula (18) was doped  
10 into Alq using as a host instead of doping Ir(phq) into CBP,  
and DCJTB was doped such that the volume ratio thereof to the  
orange light emitting layer 6 was 1.0 %:

[0113]

[Formula 24]



15

[0114]

(Comparative Example 2)

In the comparative example 2, the organic EL device was prepared in the same method as that in the inventive example  
20 4 except that NPB was not doped into the host material. The

results are shown in Table 1.

[0115]

(Evaluation 1)

The luminescent properties of each of the organic EL devices prepared in the inventive examples 1 to 6 and the comparative examples 1 and 2 were measured. Table 1 shows the structure, a material for each of layers, and the results of measurement of the luminescent properties of each of the organic EL devices prepared in the inventive examples 1 to 6 and the comparative examples 1 and 2.

[0116]

In each of the organic EL devices prepared in the inventive examples 1 to 6, Ir(phq) was doped into the organic light emitting layer 6 or 6a, so that the luminous efficiency thereof was not less than two times that in the comparative example 1. Particularly in the inventive examples 2 and 4, the luminous efficiency was significantly improved.

[0117]

In each of the organic EL devices prepared in the inventive examples 1 to 6, the ratio of the peak intensity of blue light to the peak intensity of orange light is improved. In each of the comparative examples 1 and 2, either one of the peak intensity of blue light and the peak intensity of orange light is excessively high. By comparison, in each of the organic EL devices in the inventive examples 2 to 6, the ratio of the peak intensity of blue light to the peak intensity of orange

light is smoothed. The reason for this is that by doping the assisting dopant into the blue light emitting layer 5 or the orange light emitting layer 6a, holes easily passed through the layer, and the position where electrons and holes 5 are combined with each other was changed.

[0118]

Fig. 5 is a diagram showing the spectrum of the intensity of light emitted by each of the organic EL devices prepared in the inventive examples 1, 2, and 4 and the comparative example 10 2. In Fig. 5, the ordinate axis represents the intensity of light, and the abscissa axis represents the wavelength of light.

[0119]

As shown in Fig. 5, in the organic EL device prepared in the inventive example 1, the blue light has a high peak in 15 intensity, while the orange light hardly has a peak in intensity. By comparison, in the organic EL device prepared in the inventive example 2, both the blue light and the orange light respectively have high peaks. This shows that the organic EL device in the inventive example 2 can efficiently emit white light.

20 [0120]

In the organic EL device prepared in the comparative example 2, the orange light has a high peak in intensity, while the blue light hardly has a peak in intensity. By comparison, in the organic EL device prepared in the inventive example 4, 25 both the blue light and the orange light respectively have high peaks. This shows that the organic EL device in the inventive

example 4 can efficiently emit white light.

[0121]

(Inventive Example 7)

In the inventive example 7, the organic EL device was  
5 prepared in the same method as that in the inventive example  
2 except that the volume ratio of NPB to the blue light emitting  
layer 5 was changed from 0 % to 50 %.

[0122]

(Evaluation 2)

10 The luminescent properties of the organic EL device  
prepared in the inventive example 7 were measured. Fig. 6 is  
a diagram showing the results of measurement of the relationship  
among the concentration of doped NPB, the peak luminous intensity  
of the orange light emitting layer 6, and the luminescent color  
15 (the x value of CIE (International Commission on Illumination)).

In Fig. 6, the ordinate axis represents the ratio of the peak  
luminous intensity of the orange light emitting layer 6 in a  
case where the peak luminous intensity of the blue light emitting  
layer 5 was taken as 100 and the x value of CIE, and the abscissa  
20 axis represents the concentration of NPB doped into the blue  
light emitting layer 5.

[0123]

As shown in Fig. 6, when the volume ratio of NPB exceeded  
25 10 %, the ratio of the peak intensity of the orange light emitting  
layer 6 was high.

[0124]

## (Inventive Example 8)

In the inventive example 8, the organic EL device was prepared in the same method as that in the inventive example 4 except that the volume ratio of NPB to the orange light emitting 5 layer 6a was changed from 0 % to 50 %.

[0125]

## (Evaluation 3)

The luminescent properties of the organic EL device prepared in the inventive example 8 were measured. Fig. 7 is 10 a diagram showing the results of measurement of the relationship among the concentration of doped NPB, the peak luminous intensity of the blue light emitting layer 5a, and the luminescent color (the x value of CIE).

[0126]

15 In Fig. 7, the ordinate axis represents the ratio of the peak luminous intensity of the blue light emitting layer 5a in a case where the peak luminous intensity of the orange light emitting layer 6a was taken as 100 and the x value of CIE, and the abscissa axis represents the concentration of NPB doped 20 into the orange light emitting layer 6a.

[0127]

As shown in Fig. 7, when the volume ratio of NPB exceeded 10 %, the ratio of the peak intensity of the blue light emitting layer 5a was high.

25 [Brief Description of the Drawings]

[Fig. 1]

A schematic sectional view showing an organic EL device according to a first embodiment of the present invention [Fig. 2]

A diagram showing the energy levels of the lowest unoccupied molecular orbit (LUMO) and the highest occupied molecular orbit (HOMO) of each of a hole transport layer, a blue light emitting layer, a dopant, and an assisting dopant in the organic EL device according to the first embodiment

[Fig. 3]

10 A schematic sectional view showing an organic EL device according to a second embodiment

[Fig. 4]

A diagram showing the energy levels of the lowest unoccupied molecular orbit (LUMO) and the highest occupied molecular orbit (HOMO) of each of a hole transport layer, an orange light emitting layer, a dopant, and an assisting dopant in the organic EL device according to the second embodiment

[Fig. 5]

20 A diagram showing the spectrum of the intensity of light emitted by each of organic EL devices produced in examples 1, 2, and 4 and a comparative example 2

[Fig. 6]

A diagram showing the results of measurement of the relationship among the concentration of doped NPB, the peak luminous intensity of an orange light emitting layer, and the luminescent color (the x value of CIE)

[Fig. 7]

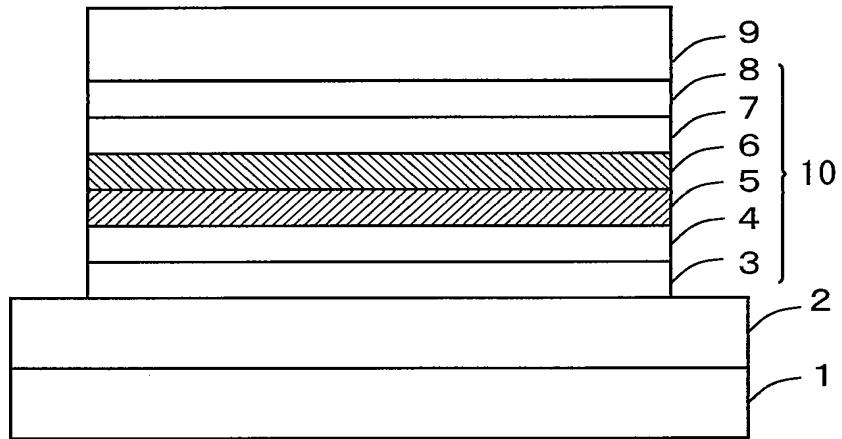
A diagram showing the results of measurement of the relationship among the concentration of doped NPB, the peak luminous intensity of a blue light emitting layer, and the  
5 luminescent color (the x value of CIE)

[Description of Reference Numerals]

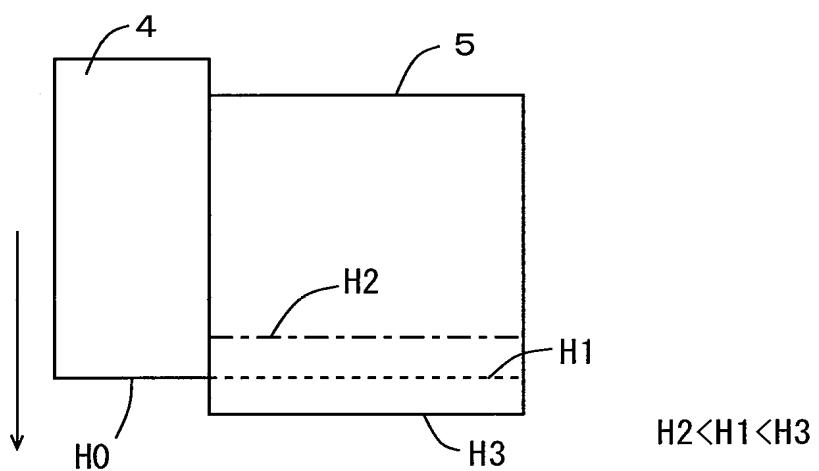
- 1 Glass substrate
- 2 Anode
- 3 Hole injection layer
- 10 4 Hole transport layer
- 5, 5a Blue light emitting layer
- 6, 6a Orange light emitting layer
- 7 Electron transport layer
- 8 Electron injection layer
- 15 9 Cathode
- 10 Organic thin film layer

[Document Name]  
[FIG. 1]

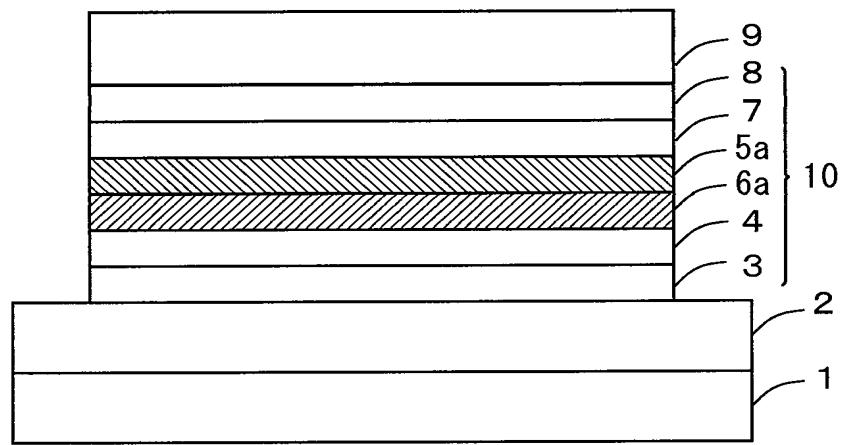
Drawings



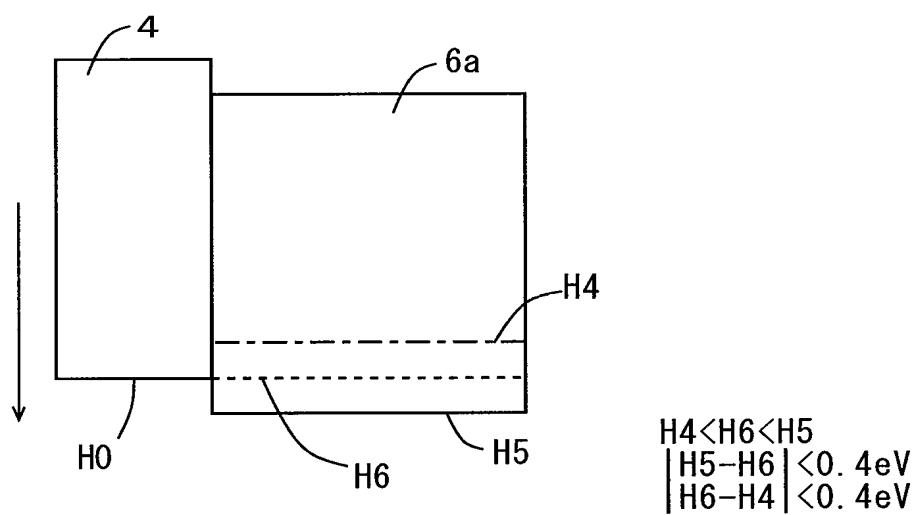
[FIG. 2]



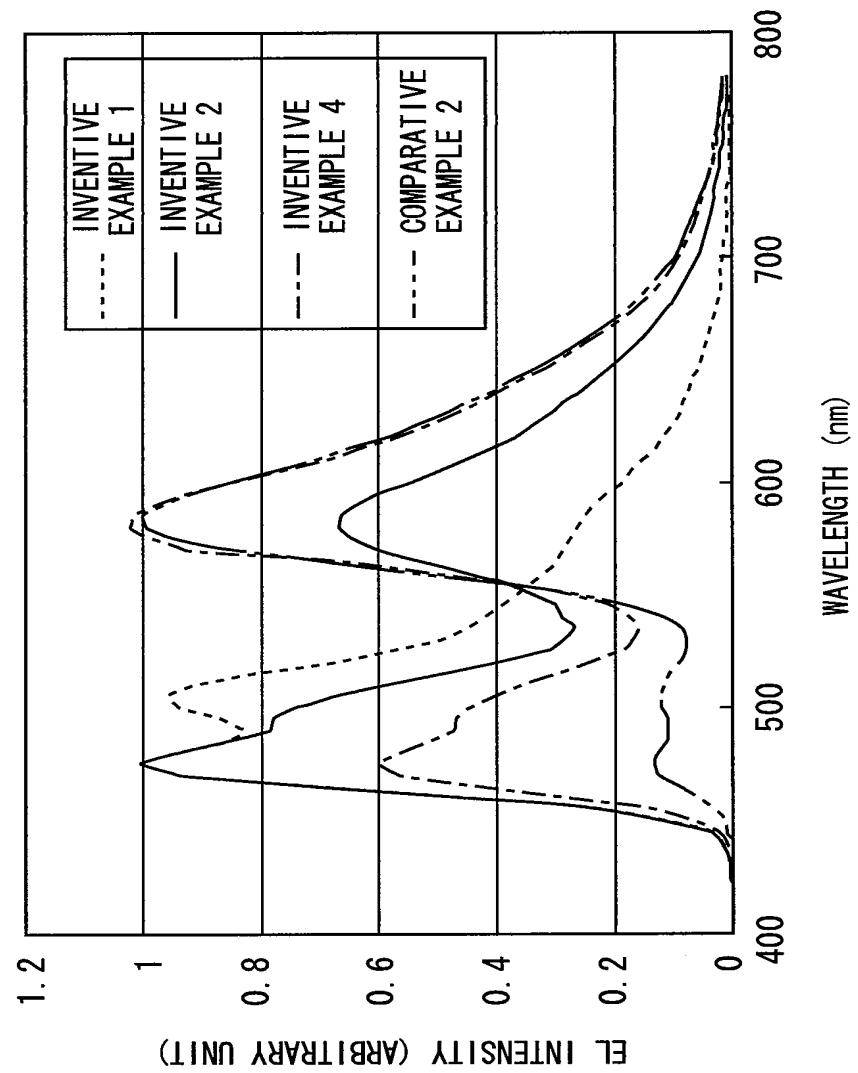
[FIG. 3]



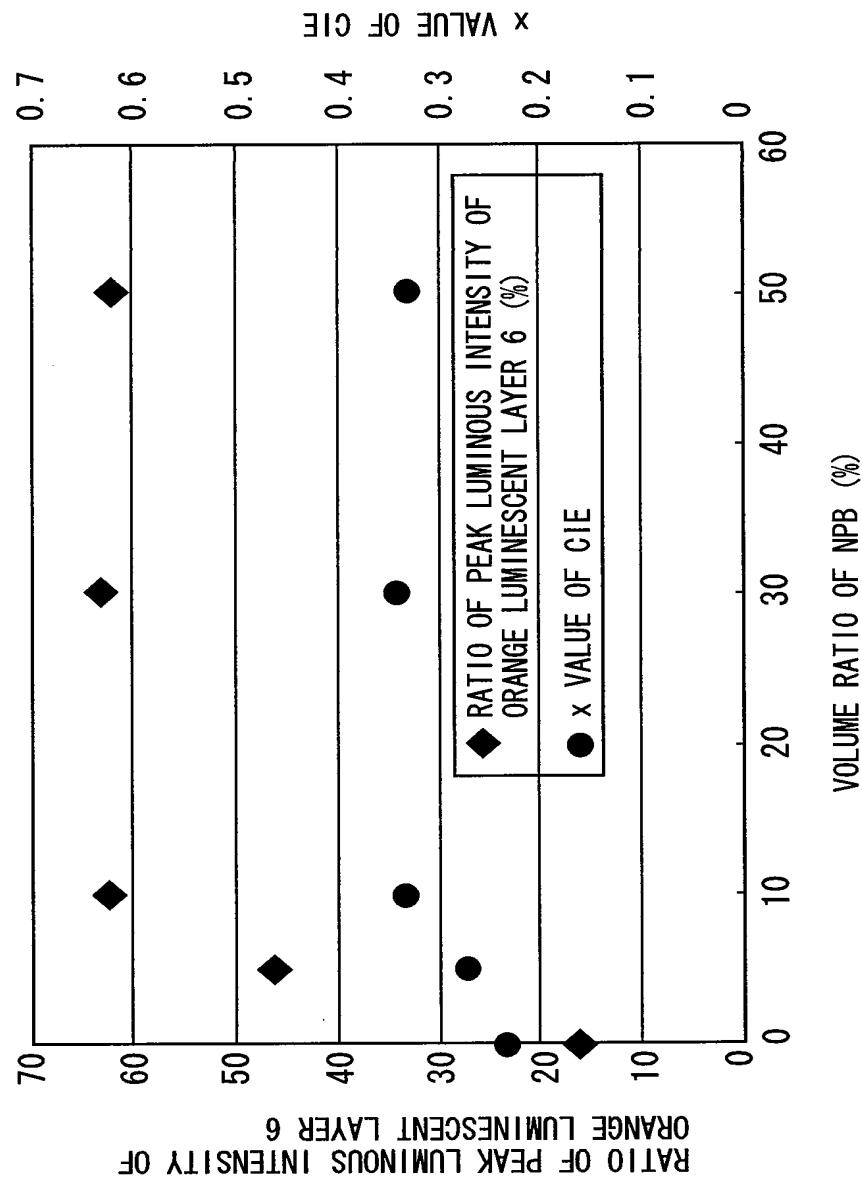
[FIG. 4]



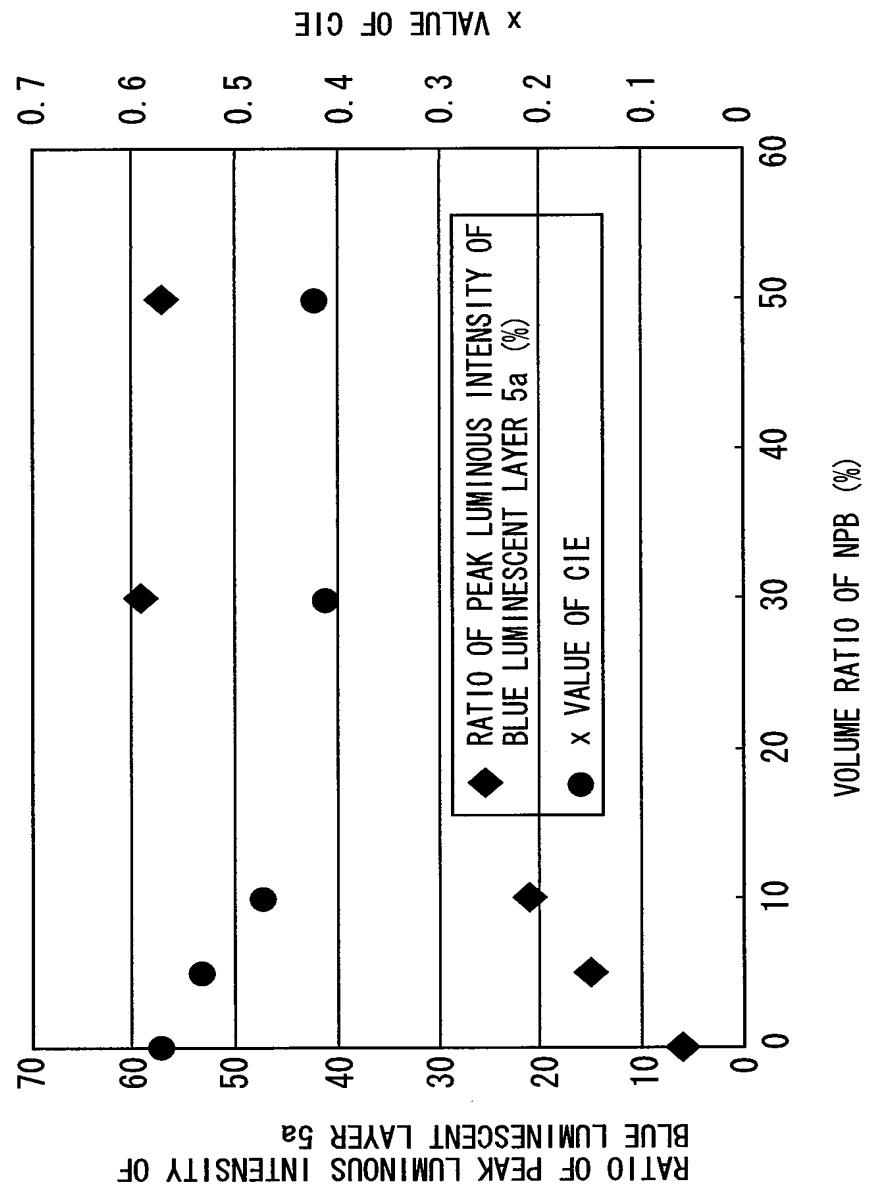
[FIG. 5]



[FIG. 6]



[FIG. 7]



[Document Name] Abstract

[Abstract]

[Subject] An organic electroluminescent device that can emit white light outward at a high efficiency is provided.

5 [Solving Means] A hole injection layer 3, a hole transport layer 4, a blue light emitting layer 5, an orange light emitting layer 6, an electron transport layer 7, an electron injection layer 8, and a cathode 9 are formed in this order on an anode 2. The blue light emitting layer 5 is composed of a host material 10 doped with an assisting dopant and a luminescent dopant emitting blue light. A material used for the hole transport layer 4 is used for the assisting dopant. The orange light emitting layer 6 is composed of a host material doped with a luminescent dopant emitting orange light.

15 [Selected Drawing] Fig. 1